ASTRONOMICAL PHOTOGRAPHY WITH PHOTOMICROGRAPHIC APPARATUS.

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On the twentieth of October, 1892, occurred a partial eclipse of the sun, which would have been visible in Syracuse, N. Y., had not clouds interfered. Early in the day, notwithstanding the overcast sky, I placed my heliostat on a shelf outside a south window*. Within the room I arranged a portrait lens of eight inches focus and a microscope in the same axial line**. The substage condenser was removed and a camera connected with the eye end of the microscope tube. Such sunlight as fell on the mirror of the heliostat was reflected through the portrait lens. The portrait lens projected an image of the clouded sun's disc, about one-twelfth of an inch in diameter, in the plane usually occupied by an object on the stage of the microscope. This tiny image was itself projected by a microscope objective of an inch and a half focus to form a second image, two inches and three-eighths in diameter, on the ground-glass of the camera. The clouds made sharp focusing impossible. Only an imperfect focus was obtained. The clock of the heliostat kept the image steadily on the ground-glass.

During the eclipse sensitised plates were substituted for the ground-glass. Exposures were made when the clouds were thin enough to permit. Thus six negatives were secured. Prints from two of these are submitted with this paper. In looking at these prints one is to imagine he looks to the south with east to his left, west to his right, north overhead and south toward the horizon. In the prints

* Fig. 39, page 147, Transactions American Microscopical Society, Vol. XIV., 1892.

** Fig. 38, page 147, Transactions American Microscopical Society, Vol. XIV., 1892.

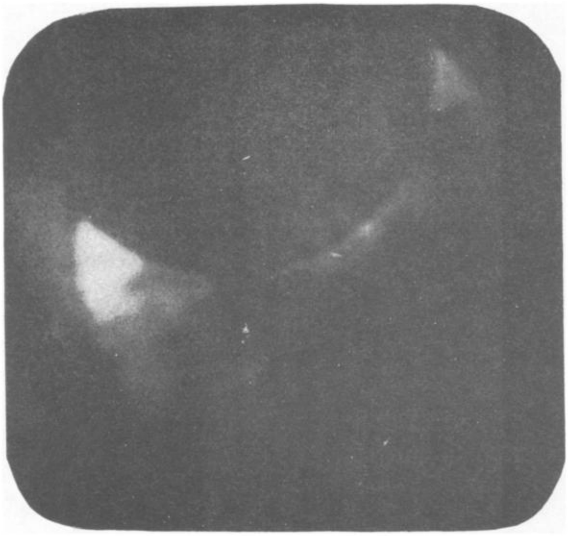

FIG. I.

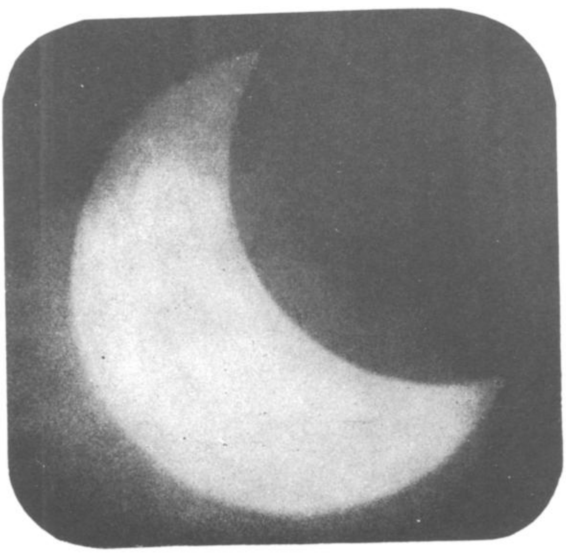

FIG. II.

the relative positions of the discs of the moon and sun are reversed from right to left, from west to east. So the first print (Plate, Fig. I.) shows the moon's black disc advancing apparently from the north-east across the sun's disc, while the second (Plate, Fig. II.) shows the moon's disc passing off to the west.

This is, I believe, the first record of an attempt to use photomicrography astronomically. All the necessary apparatus could be easily packed in a trunk, possibly in a hand-box. Such apparatus is suitable for long distance transportation. If an unaided telescope objective were used to project an image of the size obtained in our negatives, a focus of twenty-one feet would be required; and the lens would have a diameter of about sixteen inches, if made as such lenses are usually. Such an objective properly mounted would result in an instrument nearly half as large as the great Lick telescope, with its photographic objective. In other words, by using a portrait lens having a focus of fifteen or sixteen inches, a size commonly used for "cabinets" in photographers' studios, instead of the portrait lens I used, the apparatus I have described would produce a negative image equal in size to that produced by the unaided Lick lens; or, leaving my portrait lens in place, the same result could be obtained by substituting for the microscope objective of one inch and half focus another of about double the power, one of three-quarters of an inch focus. The Lick instrument has a tube about fifty feet long and forty-two inches in diameter, while my apparatus has two tubes less than one foot long and about one inch and six inches in diameter respectively. To the smaller tube is attached a camera with a bellows extending from one to six feet. Stability and freedom from vibration are comparatively very easily obtained with the small and short apparatus. The difference in housing room is great. The difference in cost is enormous. It is evident that in several respects the photomicrographic arrangement has advantages over the great Lick photographic instrument.

If, however, we turn to the matters of light and separating power, the very great superiority of the Lick objective is seen. The results given in the following tabular comparison are only approximately accurate, and I have not taken into account the loss light suffers by absorption as it passes through glass and by reflection at incident surfaces, the Lick objective consisting of three thick lenses and the photomicrographic arrangement having more than twice as many, but comparatively very thin, lenses and the mirror's reflecting surface:

	Lick photographic objective.	Larger portrait lens.	Smaller portrait lens.
Diameter of objective	33 in.	3.75 in.	2 in.
Focus of objective	550 in.	15 in.	8 in.
Focus divided by diameter	16.66	4	4
Relative value of light in first image . .	1	16	16
Size of first image	5.1 in.	.1395 in.	.0744 in.
Total equivalent focus, 550 inches, divided by diameter	16.66	147	275
Relative value of light in final image .	1	$\frac{1}{77}$	$\frac{1}{277}$
Time of exposure, eclipse of sun (about)	$\frac{1}{1800}$ sec.	$\frac{1}{30}$ sec.	$\frac{1}{6}$ sec.
Separating power	1	$\frac{1}{8.8}$	$\frac{1}{16.66}$

The tabular comparison needs no explanation, I think, excepting, perhaps, the meaning of "separating power." Other things being equal, separating power varies with the aperture or diameter of the objective. If the Lick objective, having an aperture of thirty-three inches, could barely show a certain double star as two distinct stars, it would be impossible for any objective having an aperture of four or two inches to show such a double star as two distinct stars. A star apparently single when seen through any objective having an aperture of two inches might be seen to consist of sixteen or seventeen stars in line, almost touching one another when seen through the Lick photographic objective. A star apparently single when seen through any objective having an aperture of three inches and three-quarters might be seen to consist of eight or nine stars in line, almost touching one another, when seen through the Lick photographic

objective. This power of resolving an apparent single star into two or more, or of showing the details of sun spots or other objects, is known as separating power. Notwithstanding the tabular showing, the photomicrographic arrangement has advantages in some respects as already mentioned ; and to these should be added the superior correction of aberrations now possible in lenses made of small discs of glass which are produced in great variety as to optical properties, a variety not yet realised, I believe, in large discs.